MONITORING OF POTENTIAL EXPOSURES OF MIXER-LOADERS, PILOTS, AND FLAGGERS DURING APPLICATION OF TRIBUTYL PHOSPHOROTRITHIOATE (DEF) AND TRIBUTYL PHOSPHOROTRITHIOITE (FOLEX) TO COTTON FIELDS IN THE SAN JOAQUIN VALLEY OF CALIFORNIA IN 1979

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SUMMARY

Potential inhalation and dermal exposure of mixer-loaders, pilots, and flaggers to tributyl phosphorotrithioate (DEF) and tributyl phosphorotrithioite (Folex) during defoliation of cotton were measured in the southern San Joaquin Valley of California during 1979. The analytical methodology measured DEF only since Folex readily converts to DEF during mixing. Two aerial pest control operator firms were monitored. The amount of DEF on each worker's skin and in the breathing zone was monitored for 1 to 7 hours. Using these results, estimates were made of each worker's total exposure during a 7-hour work day. It was estimated that mixer-loaders were exposed to 5,840 to 40,764 micrograms with a median of 14,270; flaggers were exposed to 2,022 to 30,782 micrograms with a median of 8,177; and pilots were exposed to 4,323 to 17,917 micrograms with a median of 7,942. Comparing these dermal levels, and assuming 10 percent of DEF or Folex is absorbed through the exposed skin of a worker, and accepting a no-observed-effect level of 0.1 mg/kg bw/day for DEF in standard test animals (chickens), it appears that an adequate margin of safety does not exist for these workers.

INTRODUCTION

In 1978, in the State of California, 3,371 applications of tributyl phosphorotrithioate (DEF) were made to 490,807 acres of cotton, using 839,675 pounds of active ingredient; and 95 applications of tributyl phosphorotrithioite (Folex) were made to 10,245 acres, using 17,612 pounds of active ingredient (State of California Pesticide Use Report, 1978). These 2 cotton defoliants are also widely used in other cotton-growing states. During the cotton defoliation season, there have been numerous complaints of mild illnesses--characterized by nausea, vomiting, upper respiratory irritation, and headaches--from persons living, working, or going to school near these treated cotton fields. It has been assumed that these illnesses are due either to the inhalation of drifting spray or to volatile forms of the two above-named defoliants, but they are more likely due to butyl mercaptan, their common degradation product, which has a very foul odor.

In 1978, the California Department of Food and Agriculture imposed use restrictions through the restricted materials permit system which prohibited applications of DEF and Folex closer than 1/2 mile to zoned residential areas. The permit restrictions have considerably minimized the exposure of persons living in towns and cities. It appears, however, from the numerous complaints received, that the exposure of residents in areas immediately adjacent to the cotton fields has not been reduced. Also, in the past, an increase in illness complaints by residents in cotton growing areas has been noted if a meteorological air inversion occurred and remained longer than 24 hours during the height of the defoliation season. The 1/2-mile buffer zone restriction probably will not be adequate to minimize exposure during prolonged air inversion periods.

In recent years, laboratory studies in test animals, particularly those by Casida et al (1963), Baron and Johnson (1964), Gaines (1969), Johnson (1970), and Abou-Donia (1978 a,b), have shown the parent chemicals DEF and Folex to be delayed neurotoxins. California Department of Food and Agriculture reports contain medical documents which show about 10 cases of systemic illness and about 2 eye-and-skin irritation cases per year due to exposure to the parent chemicals, but none have been reported to have developed delayed neurotoxicity. There has been one well-documented human illness case in Arizona with delayed neurotoxicity (Fisher, 1977) due to a spill of Folex on a mixer-loader's arm, followed by 14 weeks of disability. The delayed neurotoxicity no-observed-effect levels (NOEL) in chickens dermally exposed have been reported in the above-mentioned studies. For delayed neurotoxins, it is generally recognized by the Environmental Protection Agency that a 100-fold safety factor for chronic human exposure is needed.

Herman and Seiber (1979) measured the amounts of DEF drifting from treated cotton fields to 1/2 mile downwind areas at ideal meteorological conditions and found negligible quantities (1 mg/m^2), which suggested a margin of safety well over the 100-fold factor for persons living in these areas. Additional studies conducted in 1979 by the Department of Food and Agriculture's Environmental Monitoring Program will be forthcoming, with data on the drift potential of DEF and Folex from treated cotton fields with less than ideal meteorological conditions.

Durham and Wolfe (1962) and Wolfe (1967) made measurements of air concentration levels for inhalation exposure and the levels of concentration on cloth patches at various body sites for dermal exposure, and calculated the total amount of various organophospate pesticides that an individual worker might be exposed to; these authors' studies did not include cotton defoliants DEF and Folex. It was proposed to study the inhalation and dermal exposure potential of mixer-loaders, pilots, and flaggers during several aerial applications of DEF and Folex during the defoliation season in 1979 in the San Joaquin Valley of California.

MATERIALS AND METHODS

Two aerial application firms were selected for this study; 1 firm with a record of good compliance with established safe use regulations and work practices, and the other firm with an average compliance record. Both firms were in compliance with the Department's pesticide regulations at the time of these studies, including being licensed pest control operators, using licensed pilots, having workers trained concerning pesticide hazards, providing clean clothes daily, providing medical supervision with blood testing for cholinesterase levels, and using mechanical closed systems for mixing and loading.

Firm No. 1 utilized the Massey Aviation closed system. This system utilizes a fixed probe on a lever to puncture the container. A gasoline engine powered pump draws the pesticide out of the container and into a mix tank (approx. 50 gal. capacity). Rinse water is injected into the container through the probe, and drawn into the mix tank. Spray adjuvants, and other defoliants if necessary, are added to the mix tank. The contents of the mix tank are diluted with water and pumped into the aircraft. Additional water is then added to the aircraft hopper to obtain the desired concentration. The exit end of the loading hose is equipped with an automatic shut-off coupler to prevent spillage when the hose is disconnected from an airplane.

At the end of the work day, the mixer-loaders washed down the airplanes and cleaned out the hopper. They wore rubber boots, socks, a shirt, pants, and a washable cap. Clean long-sleeved and long-legged coveralls made of cloth were required daily. The mixer-loaders wore neoprene gloves when hooking up, loading, and washing the aircraft. They removed the gloves between mixing and loading operations and while cleaning nozzles.

In Firm No. 2, the mixer-loader transferred Folex from the original container into the aircraft hopper in a similar manner except that 2 different closed systems were used: (1) the Goodwin system, and (2) the Strong Steel system. The Strong Steel system is similar to the Massey system with 1 exception. It is not permanently fixed and, therefore, relies on operator force to puncture the container. This is considered to allow greater worker exposure due to the possibility of small spills. The Goodwin system is quite different from other closed systems observed. With this system, the 5-gallon container is placed in a box that is somewhat larger than the can. The operator then closes the lid and, using a lever

mounted outside the box, punctures a hole in the side of the can near the bottom. The pesticide then flows out of the can and into the box where it is drawn into the mix tank with a suction pump. The container is then rinsed with a jet of water directed into the container.

The rinse capabilities of these systems were not used by Firm No. 2. Instead, the probe was removed from the container, the containers were rinsed by hand, and the rinse water was hand-poured into the mix tank. The mix tank which Firm No. 2 used had an open top. This was expected to result in greater worker exposure. Firm No. 2's mixer-loaders wore rubber aprons over their coveralls.

When working with DEF or Folex, respirators are not required by regulations; they were, therefore, not worn.

The pilots for each firm had no role in mixing, loading, or aircraft cleanup. Pilots do adjust spray nozzles, but when doing this operation, they are expected to wear rubber gloves. It was observed, however, that some pilots adjusted nozzles without wearing gloves. The pilots wore shoes and socks, a helmet, and clean long-sleeved shirts and long-legged cloth pants, which were changed daily. A respirator is not required by regulation for DEF and Folex applications, and was not worn by the pilots.

The flaggers wore clean coveralls made of cloth (with long sleeves and legs) and washable caps. In common practice, flaggers do not wear gloves; however, the two female flaggers studied from Firm No. 2 on days 1 and 2 wore cloth gloves during the work day. The walking flaggers stayed in place until the plane was aimed at the field, then moved upwind one swath before the plane passed overhead. Some flaggers were exposed to drift when the wind direction changed midway through application of a field. A respirator is not required by regulations, and was not worn by flaggers during the aerial application of DEF and/or Folex.

If a good roadway was available at 1 end of the cotton field, 1 of the 2 flaggers would sometimes stay inside the pickup truck they drove to the cotton field, and mark the spot the plane was to fly over with the cab of the truck. The usual duty of the flaggers is to flag the plane swath, but sometimes they assist in hauling new containers of pesticides to an air strip.

There was clean soap and water at each work site for workers to wash their hands and faces as needed. The workers were said to have bathed or showered at the end of each work shift.

For this study, the monitoring days were selected when at least 7 hours of continuous aerial application with either DEF or Folex was expected to occur. The typical application periods were from about 5 a.m. until noon without a lunch break. It was anticipated that oral ingestion exposure would be minimal, and no attempt was made to measure such exposure. Potential inhalation exposure was measured by placing a DuPont Constant Flow Sampler P-4000 pump (at a flow rate of 200 cubic milliliters per minute) on each worker, with the air intake hose attached to the lapel of the coveralls under the chin. In the plastic air intake line, air sampling tubes containing Amberlite XAD-4 resin were inserted.

Potential exposure for exposed skin areas and skin protected by cotton coveralls was measured with patches made of an outer layer of cloth and an inner layer of gauze, taped together. These patches were taped onto or tied down to various exposed skin areas. The patches inside the taped areas were standardized, with the following dimensions in square centimeters (cm^2): back of neck, 42; front of neck, 82; face, 32; arm, 79; and leg, 79.

There was particular interest in measuring the amount of DEF that might fall onto exposed skin areas, especially the back of the neck, the face, and the front of the neck. These areas are exposed even with full-body coveralls on. Arm exposure was measured, recognizing that sometimes (illegally) on hot days in California, and (reportedly) more often in other states, short-sleeved shirts are worn. Thigh measurements were also made to give possible leg exposure data because sometimes flaggers wear short pants, even though this practice is not recommended and is illegal in California.

At the end of each work shift, the air sampling tubes were placed in separate glass jars, refrigerated at 5°C, shipped by bus to Sacramento, and received by the laboratory within 24 hours. The patches consisted of a cotton cloth outer layer (duck cloth similar to the coverall material to represent the protective factor of a coverall) over an underlying heavy cotton gauze (cheesecloth) patch (to represent the skin surface); the patches were removed from the clothing and skin areas, the taped edges were cut off, and each gauze and outer cloth patch was carefully separated and placed in separate bottles. Matched pairs of patches were placed together in glass jars (i.e., outside cloth of left and right arms were combined as were inside gauze from left and right sides of the face). Exposure of the hands was measured at the end of the work shift by rinsing the hands with about 200 ml of ethyl alcohol after removal of the gloves. These samples were also shipped to Sacramento.

Other defoliants and spray adjuvants used by the applicators along with DEF or Folex are listed in Appendix 2.

The analytical method used is described in Appendix 4.

RESULTS

The results of the various experimental data and information are summarized in the following tables:

Table 1 - Air concentration levels monitored for inhalation exposure of various workers. (Some duplicate samples were drawn through both the resin and ethylene glycol to determine the absorption efficiency of XAD-4 resin at the flow rates used since this was the first time this type of sampling procedure had been used. The results showed that the resin tube was 50 percent efficient. For this reason, the analytical results in Column 2 are doubled in Column 3 to reflect the probable actual concentration of DEF in the breathing zone.) Daily inhalation exposure (Column 4) was estimated by assuming an inhalation volume of 1.25 m^3/hour and 100 percent absorption by the lung.

Tables 2, 3, and 4 - The dermal exposure of workers determined by sampling pads. Column A is the sampling period. Column B is the results of DEF exposure in micrograms per square centimeter. Column C is an estimate of the DEF exposure in square centimeters adjusted for a typical full day's exposure. This was estimated to be 7 hours total time mixing, loading, and applying DEF. Column D is an estimate of the average area of the skin of each body part in square centimeters, according to Berkow (1931) and DuBois and DuBois (1916). This assumes an average person, weighing 70 kg and standing 175 cm. Column E is an estimate of the dermal exposure to DEF in micrograms per day to each body part. The calculations for the anterior portion of the head use a combination of DEF residues on the outside cloth and inside gauze samples placed on the cheek to represent exposure of bare skin to airborne DEF. (This assumes no face protection from respirator or shield.) Calculations for the posterior portion of the head and neck and the anterior portion of the neck use a combination of the DEF residues on the outside cloth and inside gauze sample placed on the back of the neck and front of the neck respectively. Calculations for the anterior portion of the trunk use the gauze portion of the sample taken on the front of the neck to simulate skin covered with clothing. Similarly, calculations for the posterior portion of the trunk use the gauze portion of the sample taken on the back of neck; the arms and forearms use the gauze portions of the sample taken on the forearms; and the thighs, legs, and feet use the results from the gauze portion of the sample taken on the front of the thigh just above the knee. Column F is the sum of the exposure to the body parts, excluding the hands, and inhalation exposure.

Table 5 - The dermal exposure of worker's hands using handwash sampling. Column A is the sampling period. Column B is the amount of DEF found in the sample. Column C is the amount of DEF estimated to be on the employee's hands at the end of a normal 7-hour work day.

Table 6 - Total of dermal and inhalation exposures during a full day's work with DEF.

Appendices 1 and 2 - Use pattern data and information during aerial application of DEF and Folex for defoliation of cotton fields.

Appendix 3 - Description of calculations in Tables 2-5.

DISCUSSION

Two aerial application firms were monitored. It was decided to monitor the applications exactly as they were being done rather than set up an "ideal" study with a better control of variables. Work went on at a rapid rate. Work sites were many miles apart and changed frequently. Workers were not always cooperative in keeping sampling equipment on the full time desired, so calculations had to be made to estimate some exposures. Each firm was subject to California work practices and regulations that should have resulted in less exposure than would be typical in other states of the United States. For example, the required use of clean outer coveralls daily and the closed systems for mixing and loading of DEF and/or Folex would be expected to reduce daily inhalation and dermal exposure of

workers as it has for other pesticides studied. The inhalation exposure, in micrograms per cubic meter for each type of worker, was found to be at the levels ranging from 0 to 171 for mixer-loaders, 4.8 to 155.6 ppb for pilots, and 19 to 1,912 for flaggers. In order to simulate whole body dermal exposure due to the penetration through coveralls, the patches were designed with two layers of materials. The top layer consisted of material identical to the coveralls, and the bottom layer consisted of heavy cotton gauze. The amount that penetrated the top layer was considered as the amount that might penetrate the coverall to the skin.

A legend explaining the method of calculations used in Tables 2-4 is found in Appendix 3. Clothing is sometimes worn under a worker's coveralls; usually long pants, underpants, and a shirt. The type of shirt or shirts worn depends on weather conditions and personal preference. The major potential exposure appears to be dermal. These values (excluding hand exposure), in micrograms, ranged per individual, adjusted to a 7-hour work day: for mixer-loaders, from a low of 2,728 to a high of 27,100 with a median of 7,001; for pilots, from a low of 1,693 to a high of 5,852 with a median of 2,084; and for flaggers, from a low of 632 to a high of 29,096 with a median of 7,535. These values were calculated for the unprotected skin areas of the face, front of the neck, back of the neck, and the skin of the legs and arms protected by long-sleeved and long-legged coveralls. Exposure to the hands, measured by taking hand wash samples, in micrograms, per 7-hour work day, ranged for mixer-loaders from a low of 1,148 to a high of 17,270 with a median of 5,355; for pilots, from a low of 644 to 15,960 with a median of 5,557; and for flaggers, from a low of 293 to a high of 7,910 with a median of 2,246.

It was observed during the study that the employees of Firm No. 1 seemed to have a greater proficiency than the employees of Firm No. 2 in operating their closed mixing and loading system properly. Their equipment was also simpler, it was easier to operate, and it seemed to offer fewer opportunities for employees to make careless mistakes which might result in exposure. A comparison of the total estimated DEF exposure per day of mixer-loaders in Table 6 reflects this difference. The median exposure of a mixer-loader for Firm No. 1 is estimated at 10,982 versus 16,342 micrograms for Firm 2.

The use of cotton gloves by 2 flaggers (Firm No. 2, days 1 and 2) demonstrates that the use of gloves for the flagger may be significant in reducing dermal exposure among this group of employees. It appears that exposure of the hands was a major source of contamination of all workers. Dermal exposure values are calculated, using long-sleeved coveralls from data reported in Tables 2-4.

A preliminary extrapolation using the no-observed-effect levels found by Abou-Donia's (1978) studies in the chicken for chronic exposures to the total amount of DEF or Folex found on the skin of these workers suggests that, unless there is negligible skin absorption of DEF in man, there is little or no safety factor against the delayed neurotoxic potential of DEF or Folex.

Neither registrant has provided dermal absorption rate data. Since oral LD_{50} averages about 200 mg/kg, and dermal LD_{50} averages about 1,000 mg/kg,

200/1000 suggests a dermal transport rate of 20 percent. A 10 percent rate is perhaps conservative. It is logical to ask that if there is little or no safety factor, why are nerve damage cases being seen. It is quite possible that since exposure of workers only occurs for 7-8 hours per day for 5 days per week for 2 to 3 weeks per year, workers do not absorb an amount great enough to cause nerve damage.

The chronic exposure NOEL in the chicken appears to be similar for DEF and leptophos (Phosvel) with respect to delayed neurotoxicity. The experimental use of leptophos as a pesticide in the United States was brought to a halt by the EPA after several thousand water buffalo were paralyzed in Egypt after being poisoned with leptophos, and indications of human poisoning were also present. After use ceased in the United States, manufacture for export continued. As a result of diagnoses of cases of encephalitis and multiple sclerosis, and complaints by workers, the National Institute of Occupational Health conducted a health survey of persons who had been involved in the manufacture of leptophos. A substantial number of the workers examined were found to have neurological, electromyographic, electroneurographic, and psychological performance abnormalities. In this factory, it was difficult to identify leptophos as the possible sole cause of these abnormalities because of the simultaneous exposure to a common solvent, n-hexane, which can cause neurologic effects.

A companion report detailing the margin of safety of the exposure levels to DEF and Folex observed in this study will be developed by the Hazard Evaluation Division, Office of Pesticide Programs, Environmental Protection Agency, Washington, D.C., using the results of this study.

CONCLUSIONS

Abou-Donia's study showed the no-observed-effect-level (NOEL) for delayed neurotoxicity in the chicken to be 0.1 mg/kg of body weight (bw) per day for chronic exposure. If one assumes (a) a 0.1 mg/kg bw/day NOEL for human chronic exposure, and (b) a 10 percent skin absorption of the total DEF estimated to come in contact with the skin, and calculates the exposure level, it appears that little or no margin of safety exists for these workers during aerial application of DEF or Folex. For example: for flaggers, the lowest value found of 1.5 mg per day of dermal exposure, assuming a 70-kg person and 10 percent absorption through the skin:

$$\frac{1.5 \text{ mg} \times .10}{70 \text{ kg.}} = \frac{0.15}{70} = 0.002 \text{ mg/kg bw/day}$$

$$\text{Margin of safety} = \frac{.1}{0.002} = 50$$

This is less than the desirable 100-fold safety factor.

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TABLE 1

Amount of DEF Found in the Breathing Zone of Employees
During Aerial Defoliation of Cotton Fields
Expressed as Time-Weighted-Average Values

Firm and Day Number	Worker	Column 1 PPB (V.V.)	Column 2 ug/m^3	Column 3 Probable Actual Concentration (ug/m^3) 1/	Column 4 Estimated Daily Inhalation Exposure (ug)
Firm 1, Day 2	Mix-Load 1	6.7	85.5	171.	1,496
	Mix-Load 2	1.3	17.3	34.6	303
Day 3	Mix-Load 1	1.6	21.	42.0	367
	Mix-Load 2	2.4	30.6	61.2	535
Day 4	Mix-Load 1	N.D.	N.D.	0.0	0
Firm 2, Day 1	Mix-Load 1	3.1	40.4	80.8	707
	Mix-Load 2	2.6	32.8	65.6	574
Day 2	Mix-Load 1	3.4	43.8	87.6	766
	Mix-Load 2	0.4	5.3	10.6	92
Firm 1, Day 1	Pilot 1	0.2	2.8	5.6	49
	Pilot 2	2.1	28.2	56.4	473
Day 2	Pilot 1	0.3	3.6	7.2	63
	Pilot 2	0.7	8.6	17.2	150
Day 3	Pilot 1	0.8	10.5	21.0	184
	Pilot 2	0.5	6.3	12.6	110
Day 4	Pilot 1	6.0	77.8	155.6	1,361
Firm 2, Day 1	Pilot 1	0.4	4.5	9.0	79
	Pilot 2	0.2	2.4	4.8	42
Day 2	Pilot 1	0.4	4.5	9.0	79
Firm 1, Day 1	Flagger 1	1.2	15.9	31.8	278
	Flagger 2	2.2	28.8	57.6	504
Day 2	Flagger 1	0.6	9.1	18.2	159
	Flagger 2	7.4	95.6	1,912.	1,673
Day 3	Flagger 1	0.7	9.5	19.0	166
	Flagger 2	3.4	42.0	84.0	735
Day 4	Flagger 1	4.2	540.	1,080.	9,450
Firm 2, Day 1	Flagger 1	5.1	65.5	131.	1,146
	Flagger 2	1.9	25.1	50.2	439
Day 2	Flagger 1	6.2	79.6	1,592.	1,393
	Flagger 2	0.9	11.0	22.0	192

1/ This was the first time XAD-4 resin had been used in portable air samplers to measure DEF. Several stationary samplers were also set-up near the mix tank that pulled air through ethylene glycol after pulling it through the resin. This revealed approximately a 50 percent breakthrough rate of DEF through the resin.

N.D. - none detected (minimum detectable limit: $2ug/m^3$)

TABLE 2

Amount of DEF Measured On Various Skin Areas of Mixer/Loaders
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A Hours of Exposure	Column B Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B Inside Gauze	Column C Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C Inside Gauze	Column D Area of Skin Surface (cm^2) Covered	Column D Bare	Column E Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E Bare Skin	Column F Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #1 Day 1	1	Face & Head Anterior	0.75	0.125	0.0156	1.1667	0.1456		650		853.00	
		Neck Anterior	7	0.1159	0.0061	0.1159	0.0961		160		19.52	
		Head & Neck Posterior	7	0.4167	0.0357	0.4167	0.0357		300		135.72	
		Trunk, Anterior	7	0.1159	0.0061	1.1159	0.0061	3,700		22.57		
		Trunk, Posterior	7	0.4167	0.0357	0.4167	0.0357	3,330		118.88		
		Arms and Forearms	7	5.45	0.035	5.45	0.035	2,497.5		87.41		
		Thigh, Legs and Feet	7	15.025	0.42	15.025	0.42	7,030		2,952.6		
		TOTAL										4,189.70
Day 2	1	Face & Head Anterior	5	0.5889	0.0045	2.1404[a/]	0.0798[a/]		650		1,443.13	
		Neck Anterior	5	0.5889	0.0045	0.8245	0.0063		60		132.93	
		Head & Neck Posterior	5	0.6855	0.0221	0.9597	0.0309		300		297.18	
		Trunk, Anterior	5	0.5889	0.0045	0.8245	0.0063	3,700		23.31		
		Trunk, Posterior	5	0.6855	0.0221	0.9597	0.0309	3,330		102.90		
		Arms and Forearms	6.5	6.4675	6.0382	6.9650	0.0411	2,497.5		102.89		
		Thigh, Legs and Feet	6.5	2.2196	2.1028	2.3903	0.1107	7,030		778.22		
		TOTAL										2,880.56

TABLE 2 - (Continued)

Amount of DEF Measured On Various Skin Areas of Mixer/Loaders
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A: Hours of Exposure	Column B: Amount of DEP-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B: Amount of DEP-6 On Cloth Pads (ug/cm^2) Inside Gauze	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Inside Gauze	Column D: Area of Skin Surface (cm^2) Covered	Column D: Area of Skin Surface (cm^2) Bare	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Bare Skin	Column F: Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Day 2	2	Face & Head Anterior	1.50	0.6673	0.0030	3.1141	0.0140		650		2,033.27	
		Neck Anterior	6.5	0.9739	0.0045	1.0488	0.0048		160		168.58	
		Head & Neck Posterior	6.5	0.995	0.0045	1.0715	0.0048		300		322.89	
		Trunk, Anterior	6.5	0.9739	0.0045	1.0488	0.0048	3,700		17.76		
		Trunk, Posterior	6.5	0.9959	0.0045	1.0715	0.0048	3,330		15.98		
		Arms and Forearms	6.5	21.8134	0.0382	23.4914	0.0411	2,497.5		102.65		
		Thigh, Legs and Feet	6.5	7.3859	0.0382	7.9540	0.0411	7,030		288.93		
		TOTAL										2,950.06
Day 3	1	Face & Head Anterior				2.1404[a/]	0.0798[a/]		650		1,443.13	
		Neck Anterior	5	0.8854	0.0329	1.2396	0.0461		160		205.71	
		Head & Neck Posterior	5	0.6029	0.0429	0.8441	0.0601		300		271.26	
		Trunk, Anterior	5	0.8854	0.0329	1.2396	0.0461	3,700		170.57		
		Trunk, Posterior	5	0.6029	0.0429	0.8441	0.0601	3,330		200.13		
		Arms and Forearms	5	0.1984	0.1068	0.2778	0.1495	2,497.5		373.38		
		Thigh, Legs and Feet	5	242.2051	0.4346	339.0871	0.6084	7,030		4,277.05		
		TOTAL										6,341.23

TABLE 2 - (Continued)

Amount of DEF Measured On Various Skin Areas of Mixer/Loaders
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A: Hours of Exposure	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2) Inside Gauze	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Inside Gauze	Column D: Area of Skin Surface (cm^2) Covered	Column D: Area of Skin Surface (cm^2) Bare	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Bare Skin	Column F: Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Day 3	2	Face & Head Anterior				2.1404[a]	0.0798[a]		605		1,443.13	
		Neck Anterior	5	0.4804	0.1180	0.6726	0.1652		160		134.05	
		Head & Neck Posterior	5	0.3617	0.0295	0.5064	0.0413		300		164.31	
		Trunk, Anterior	5	0.4804	0.1180	0.6726	0.1652	3,700		611.24		
		Trunk, Posterior	5	0.3617	0.0295	0.5064	0.0413	3,330		134.05		
		Arms and Forearms	5	1.4247	0.0178	1.9946	0.0249	2,497.5		62.19		
		Thigh, Legs and Feet	5	4.7016	0.0178	6.5822	0.0249	7,030		175.05		
		TOTAL										2,727.50
Day 4	1	Face & Head Anterior				2.1404[a]	0.0798[a]		650		1,443.13	
		Neck Anterior				0.7803[a]	0.0457[a]		160		132.16	
		Head & Neck Posterior				0.7597[a]	0.0346[a]		300		238.29	
		Trunk, Anterior				0.7803[a]	0.0457[a]	3,700		169.09		
		Trunk, Posterior				0.7597[a]	0.0346[a]	3,330		115.22		
		Arms and Forearms				7.6358[a]	0.0583[a]	2,497.5		145.60		
		Thigh, Legs and Feet	1	2.7215	0.1101	19.0505	0.7707	7,030		5,418.02		
		TOTAL										7,661.51

TABLE 2 - (Continued)

Amount of DEF Measured On Various Skin Areas of Mixer/Loaders
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A Hours of Exposure	Column B Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B Inside Gauze	Column C Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C Inside Gauze	Column D Area of Skin Surface (cm^2) Covered	Column D Bare	Column E Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E Bare Skin	Column F Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #2 Day 1	1	Face & Head Anterior				1.7773[a/]	0.1952[a/]		650		1,282.13	
		Neck Anterior	7	1.7073	0.0374	1.7073	0.0374		160		279.15	
		Head & Neck Posterior	7	0.5476	0.0357	0.5476	0.0357		300		174.99	
		Trunk, Anterior	7	1.7073	0.0374	1.7073	0.0374	3,700		138.38		
		Trunk, Posterior	7	0.5476	0.0357	0.5476	0.0357	3,330		118.88		
		Arms and Forearms	7	2.3418	0.1348	2.3418	0.1348	2,497.5		336.66		
		Thigh, Legs and Feet	7	12.8481	1.0127	12.8481	1.0127	7,030		7,119.28		
		TOTAL										9,449.47
Day 1	2	Face & Head Anterior				1.7773[a/]	0.1952[a/]		650		1,282.13	
		Neck Anterior	7	2.8049	0.0613	2.8049	0.0613		160		458.59	
		Head & Neck Posterior	7	2.3024	0.0498	2.3024	0.0498		300		705.66	
		Trunk, Anterior	7	2.8049	0.0613	2.8049	0.0613	3,700		226.81		
		Trunk, Posterior	7	2.3024	0.0498	2.3024	0.0498	3,330		165.83		
		Arms and Forearms	7	20.6329	5.1899	20.6329	5.1899	2,497.5		12,961.78		
		Thigh, Legs and Feet	7	13.3544	1.0127	13.3544	1.0127	7,030		7,119.28		
		TOTAL										22,920.08

TABLE 2 - (Continued)

Amount of DEF Measured On Various Skin Areas of Mixer/Loaders
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A Hours of Exposure	Column B Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B Inside Gauze	Column C Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C Inside Gauze	Column D Area of Skin Surface (cm^2) Covered	Column D Bare	Column E Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E Bare Skin	Column F Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #2 Day 2	1	Face & Head Anterior	1	0.1953	0.0488	1.3671	0.3416		650		1,110.66	
		Neck Anterior	7	0.6220	0.0202	0.6220	0.0202		160		102.75	
		Head & Neck Posterior	7	4.7619	0.1981	4.7619	0.1981		300		1,488.00	
		Trunk, Anterior	7	0.6220	0.0202	0.6220	0.0202	3,700		74.74		
		Trunk, Posterior	7	4.7619	0.1981	4.7619	0.1981	3,330		659.67		
		Arms and Forearms	7	2.4051	0.1184	2.4051	0.1184	2,497.5		295.70		
		Thigh, Legs and Feet	7	8.2911	0.7025	0.2911	0.7025	7,030		4,938.58		
		TOTAL										8,670.10
Day 2	2	Face & Head Anterior	1.5	2.1875	0.0488	2.1875	0.0488		650		1,453.60	
		Neck Anterior	7	2.8049	0.1268	2.8049	0.1268		160		469.07	
		Head & Neck Posterior	7	2.0548	0.1486	2.0548	0.1486		300		661.02	
		Trunk, Anterior	7	2.8049	0.1268	2.8049	0.1268	3,700		469.16		
		Trunk, Posterior	7	2.0548	0.1486	2.0548	0.1486	3,330		494.84		
		Arms and Forearms	7	6.9367	1.0570	6.9367	1.0570	2,497.5		2,639.86		
		Thigh, Legs and Feet	7	47.9747	2.9747	47.9747	2.9747	7,030		20,912.14		
		TOTAL										27,099.69

[a] Estimated Value - Calculated by taking average of other mixer/loaders with same firm for the same skin area.

TABLE 3

Concentration of DEF Measured On Various Skin Areas of Pilots
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A: Hours of Exposure	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2) Inside Gauze	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Inside Gauze	Column D: Area of Skin Surface (cm^2) Covered	Column D: Area of Skin Surface (cm^2) Bare	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Bare Skin	Column F: Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #1 Day 1	1	Face & Head Anterior				0.226[b]	0.0271[b]		650		164.52	
		Neck Anterior				0.226[b]	0.0271[b]		160		40.50	
		Head & Neck Posterior				0.226[b]	0.0271[b]		300		75.93	
		Trunk, Anterior				0.226[b]	0.0271[b]	3,700		100.27		
		Trunk, Posterior				0.226[b]	0.0271[b]	3,330		90.24		
		Arms and Forearms				1.4441[a]	0.1631[a]	2,497.5		407.34		
		Thigh, Legs and Feet				2.2813[a]	0.1715[a]	7,030		1,205.65		
		TOTAL										2,084.45
Day 1	2	Face & Head Anterior				0.226[b]	0.0271[b]		650		164.52	
		Neck Anterior				0.226[b]	0.0271[b]		160		40.50	
		Head & Neck Posterior				0.226[b]	0.0271[b]		300		75.93	
		Trunk, Anterior				0.226[b]	0.0271[b]	3,700		100.27		
		Trunk, Posterior				0.226[b]	0.0271[b]	3,330		90.24		
		Arms and Forearms				1.4441[a]	0.1613[a]	2,497.5		407.34		
		Thigh, Legs and Feet				2.2813[a]	0.1715[a]	7,030		1,205.65		
		TOTAL										2,084.45

TABLE 3 - (Continued)

Concentration of DEF Measured On Various Skin Areas of Pilots
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A: Hours of Exposure	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2) Inside Gauze	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Inside Gauze	Column D: Area of Skin Surface (cm^2) Covered	Column D: Area of Skin Surface (cm^2) Bare	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Bare Skin	Column F: Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #1 Day 2	1	Face & Head Anterior		0.335[c]	0.0177[c]	0.3608	0.0191		650		246.94	
		Neck Anterior		0.335[c]	0.0177[c]	0.3608	0.0191		160		60.78	
		Head & Neck Posterior		0.335[c]	0.0177[c]	0.3608	0.0191		300		113.97	
		Trunk, Anterior		0.335[c]	0.0177[c]	0.3608	0.0191	3,700		70.67		
		Trunk, Posterior		0.335[c]	0.0177[c]	0.3608	0.0191	3,330		63.60		
		Arms and Forearms				1.4441[a]	0.0631[a]	2,497.5		407.34		
		Thigh, Legs and Feet				2.2813[a]	0.1715[a]	7,030		1,205.65		
		TOTAL										2,168.95
Day 2	2	Face & Head Anterior		0.0411[c]	0.0035[c]	0.0443	0.0038		650		31.27	
		Neck Anterior		0.0411[c]	0.0035[c]	0.0443	0.0038		160		7.70	
		Head & Neck Posterior		0.0411[c]	0.0035[c]	0.0443	0.0038		300		14.43	
		Trunk, Anterior		0.0411[c]	0.0035[c]	0.0443	0.0038	3,700		14.06		
		Trunk, Posterior		0.0411[c]	0.0035[c]	0.0443	0.0038	3,330		12.65		
		Arms and Forearms				1.4441[a]	0.1631[a]	2,497.5		407.34		
		Thigh, Legs and Feet				2.2813[a]	0.1715[a]	7,030		1,205.65		
		TOTAL										1,693.10

TABLE 3 - (Continued)

Concentration of DEF Measured On Various Skin Areas of Pilots
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A: Hours of Exposure	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2) Inside Gauze	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Inside Gauze	Column D: Area of Skin Surface (cm^2) Covered	Column D: Area of Skin Surface (cm^2) Bare	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Bare Skin	Column F: Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #1 Day 3	1	Face & Head Anterior	5	0.0713[c]/	0.0043[c]/	0.0998	0.006		650		68.77	
		Neck Anterior	5	0.0713[c]/	0.0043[c]/	0.0998	0.006		160		16.93	
		Head & Neck Posterior	5	0.0713[c]/	0.0043[c]/	0.0998	0.006		300		31.74	
		Trunk, Anterior	5	0.0713[c]/	0.0043[c]/	0.0998	0.006	3,700		22.2		
		Trunk, Posterior	5	0.0713[c]/	0.0043[c]/	0.0998	0.006	3,330		19.98		
		Arms and Forearms				1.4441[a]/	0.0631[a]/	2,497.5		407.34		
		Thigh, Legs and Feet				2.2813[a]/	0.1715[a]/	7,030		1,205.65		
		TOTAL										1,772.61
Day 3	2	Face & Head Anterior	5	0.0855[c]/	0.0078[c]/	0.1197	0.0109		650		390.85	
		Neck Anterior	5	0.0855[c]/	0.0078[c]/	0.1197	0.0109		160		96.21	
		Head & Neck Posterior	5	0.0855[c]/	0.0078[c]/	0.1197	0.0109		300		180.39	
		Trunk, Anterior	5	0.0855[c]/	0.0078[c]/	0.1197	0.0109	3,700		40.33		
		Trunk, Posterior	5	0.0855[c]/	0.0078[c]/	0.1197	0.0109	3,330		36.30		
		Arms and Forearms				1.4441[a]/	0.1631[a]/	2,497.5		407.34		
		Thigh, Legs and Feet				2.2813[a]/	0.1715[a]/	7,030		1,205.65		
		TOTAL										2,954.62

TABLE 3 - (Continued)

Concentration of DEF Measured On Various Skin Areas of Pilots
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

m No. / No Days ıdied	Worker Number	Skin Area Studied	Column A: Hours of Exposure	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2) Inside Gauze	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Inside Gauze	Column D: Area of Skin Surface (cm^2) Covered	Column D: Area of Skin Surface (cm^2) Bare	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Bare Skin	Column F: Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
n #1 4	1	Face & Head Anterior	1	0.0722[c]	0.0137[c]	0.5054	0.0959		650		390.85	
		Neck Anterior	1	0.0722[c]	0.0137[c]	0.5054	0.0959		160		96.21	
		Head & Neck Posterior	1	0.0722[c]	0.0137[c]	0.5054	0.0959		300		180.39	
		Trunk, Anterior	1	0.0722[c]	0.0137[c]	0.5054	0.0959	3,700		354.83		
		Trunk, Posterior	1	0.0772[c]	0.0137[c]	0.5054	0.0959	3,330		319.35		
		Arms and Forearms	1	0.2063	0.0233	1.4441	0.1631	2,497.5		407.34		
		Thigh, Legs and Feet	1	0.3259	0.0245	2.2813	0.1715	7,030		1,205.65		
		TOTAL										2,954.62
m #2 1	1	Face & Head Anterior	1	0.7547	0.0194	5.2829	0.1358		650		3,522.16	
		Neck Anterior	1	0.0939	0	0.6573	0		160		105.17	
		Head & Neck Posterior	1	0.1619	0.0107	1.1333	0.0749		300		362.46	
		Trunk, Anterior	1	0.0939	0	0.6573	0	3,700		0		
		Trunk, Posterior	1	0.1619	0.0107	1.1333	0.0749	3,330		249.42		
		Arms and Forearms				1.4441[a]	0.1631[a]	2,497.5		407.34		
		Thigh, Legs and Feet				2.2813[a]	0.1715[a]	7,030		1,205.65		
		TOTAL										5,852.20

TABLE 3 - (Continued)

Concentration of DEF Measured On Various Skin Areas of Pilots
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A: Hours of Exposure	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2)		Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2)		Column D: Area of Skin Surface (cm^2)		Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms)		Column F: Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
				Outside Cloth	Inside Gauze	Outside Cloth	Inside Gauze	Covered	Bare	Covered Skin	Bare Skin	
Firm #2 Day 1	2	Face & Head Anterior	1	0.1003	0.0191	0.7021	0.1337		650		543.27	
		Neck Anterior	1	0.1512	0.0195	1.0584	0.1365		160		191.18	
		Head & Neck Posterior	1	0.1086	0.0219	0.7602	0.1533		300		274.05	
		Trunk, Anterior	1	0.1512	0.0195	1.0584	0.1365	3,700		505.05		
		Trunk, Posterior	1	0.1086	0.0219	0.7602	0.1533	3,330		510.49		
		Arms and Forearms				1.4441[a]	0.1631[a]	2,497.5		407.34		
		Thigh, Legs and Feet				2.2813[a]	0.1715[a]	7,030		1,205.65		
		TOTAL										3,637.03
Day 2	1	Face & Head Anterior	1.5	0.1906	0.1364	0.8895	0.6365		650		991.9	
		Neck Anterior	6.25	0.1537	0.0139	0.1721	0.0156		160		30.03	
		Head & Neck Posterior	6.25	0.1721	0	0.1928	0		300		57.84	
		Trunk, Anterior	6.25	0.1537	0.0139	0.1721	0.0156	3,700		57.72		
		Trunk, Posterior	6.25	0.1721	0	0.1928	0	3,330		0		
		Arms and Forearms				1.4441[a]	0.1631[a]	2,497.5		407.34		
		Thigh, Legs and Feet				2.2813[a]	0.1715[a]	7,030		1,205.65		
		TOTAL										2,750.48

TABLE 3 - (Continued)

Concentration of DEF Measured On Various Skin Areas of Pilots
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A Hours of Exposure	Column B Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B Inside Gauze	Column C Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C Inside Gauze	Column D Area of Skin, (cm^2) Covered	Column D Bare	Column E Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E Bare Skin	Column F Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #2 Day 2	2	Face & Head Anterior	1	0.3656	0	2.5592	0		650		1,663.48	
		Neck Anterior	6.25	0.1951	0.0212	0.2185	0.0237		160		38.75	
		Head & Neck Posterior	6.25	0.3381	0.0114	0.3787	0.0128		300		117.45	
		Trunk, Anterior	6.25	0.1951	0.0212	0.2185	0.0237	3,700		87.69		
		Trunk, Posterior	6.25	0.3381	0.0114	0.3787	0.0128	3,330		42.62		
		Arms and Forearms				1.4441[a]	0.1631[a]	2,497.5		407.34		
		Thigh, Legs and Feet				2.2813[a]	0.1715[a]	7,030		1,205.65		
		TOTAL										3,562.98

[a] Estimated Value - Uses value obtained from Firm #1, Day 4. (This is the only forearm and leg data available for pilots.)

[b] Estimated Value - Calculated by taking average of other pilots with the same firm for the same skin area.

[c] Estimated Value - Calculated from sample taken on cockpit bulkhead. (In samples taken for comparison patches on the cockpit wall were found to contain concentrations of DEF comparable to face, neck front, and neck back patches.)

TABLE 4

Concentration of DEF Measured On Various Skin Areas of Flaggers
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A Hours of Exposure	Column B Amount of DEF-6 On Cloth Pads ($\mu g/cm^2$) Outside Cloth	Column B Amount of DEF-6 On Cloth Pads ($\mu g/cm^2$) Inside Gauze	Column C Estimated DEF Exposure Adjusted To 7-Hour Day ($\mu g/cm^2$) Outside Cloth	Column C Estimated DEF Exposure Adjusted To 7-Hour Day ($\mu g/cm^2$) Inside Gauze	Column D Area of Skin Surface (cm^2) Covered	Column D Area of Skin Surface (cm^2) Bare	Column E Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Bare Skin	Column F Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #1 Day 1	1	Face & Head Anterior	7	4.0625	0.0625	4.0625	0.0625		650		2,681.25	
		Neck Anterior	7	0.4939	0.0427	0.4939	0.0427		160		85.86	
		Head & Neck Posterior	7	10.7143	0.0476	10.7143	0.0476		300		3,228.57	
		Trunk, Anterior	7	0.4939	0.0427	0.4939	0.0427	3,700		157.99		
		Trunk, Posterior	7	10.7143	0.0476	10.7143	0.0476	3,330		158.51		
		Arms and Forearms	7	5.155	0.18	5.155	0.18	2,497.5		449.55		
		Thigh, Legs and Feet	7	3.575	0.11	3.575	0.11	7,030		773.30		
		TOTAL										7,535.04
	2	Face & Head Anterior	7	0.1401	0.0623	0.1401	0.0623		650		131.56	
		Neck Anterior	7	0.2073	0.0037	0.2073	0.0037		160		33.76	
		Head & Neck Posterior	7	0.7024	0.0107	0.7024	0.0107		300		213.93	
		Trunk, Anterior	7	0.2073	0.0037	0.2073	0.0037	3,700		13.69		
		Trunk, Posterior	7	0.7024	0.0107	0.7024	0.0107	3,330		35.63		
		Arms and Forearms	7	0.695	0.025	0.695	0.025	2,497.5		62.44		
		Thigh, Legs and Feet	7	0.98	0.02	0.98	0.02	7,030		140.6		
		TOTAL										631.61

TABLE 4

Concentration of DEF Measured On Various Skin Areas of Flaggers
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A Hours of Exposure	Column B Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B Amount of DEF-6 On Cloth Pads (ug/cm^2) Inside Gauze	Column C Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Inside Gauze	Column D Area of Skin Surface (cm^2) Covered	Column D Area of Skin Surface (cm^2) Bare	Column E Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Bare Skin	Column F Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #1 Day 2	1	Face & Head Anterior	6.5	1.4655	0.0030	1.5782	0.0032		650		1,027.91	
		Neck Anterior	6.5	2.1968	0.0170	2.3658	0.0115		160		612.38	
		Head & Neck Posterior	6.5	1.7024	0.0419	1.8334	0.0451		300		563.55	
		Trunk, Anterior	6.5	2.1968	0.0170	2.3658	0.0115	3,700		42.55		
		Trunk, Posterior	6.5	1.7024	0.0419	1.8334	0.0451	3,330		150.18		
		Arms and Forearms	6.5	0.9403	0.0235	1.0126	0.0253	2,497.5		63.19		
		Thigh, Legs and Feet	6.5	1.2246	0.1381	1.3188	0.1487	7,030		1,045.36		
		TOTAL										3,05512
Day 2	2	Face & Head Anterior	6.5	5.7631	1.1897	6.2063	1.2812		650		4,866.88	
		Neck Anterior	6.5	2.8757	0.0452	3.0969	0.0487		160		503.30	
		Head & Neck Posterior	6.5	13.8205	0.9838	14.8836	1.0595		300		4,782.93	
		Trunk, Anterior	6.5	2.8757	0.0452	3.0969	0.0487	3,700		180.19		
		Trunk, Posterior	6.5	13.8205	0.9838	14.8836	1.0595	3,330		3,528.14		
		Arms and Forearms	6.5	53.5767	0.3056	57.6980	0.3291	2,497.5		821.93		
		Thigh, Legs and Feet	6.5	13.7003	0.3203	14.7542	0.3449	7,030		2,424.65		
		TOTAL										17,108.04

TABLE 4 - (Continued)

Concentration of DEF Measured On Various Skin Areas of Flaggers
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A Hours of Exposure	Column B Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B Inside Gauze	Column C Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C Inside Gauze	Column D Area of Skin Surface (cm^2) Covered	Column D Bare	Column E Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E Bare Skin	Column F Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #1 Day 3	1	Face & Head Anterior	5	0.3694	0.0123	0.5172	0.0172		650		347.36	
		Neck Anterior	5	0.6932	0.0096	0.9705	0.0134		160		157.42	
		Head & Neck Posterior	5	0.1607	0.0402	0.2250	0.0563		300		84.39	
		Trunk, Anterior	5	0.6932	0.0096	0.9705	0.0134	3,700		49.58		
		Trunk, Posterior	5	0.1607	0.0402	0.2205	0.0563	3,330		187.48		
		Arms and Forearms	5	1.1398	0.0114	0.5957	0.0160	2,497.5		39.96		
		Thigh, Legs and Feet	5	1.7809	0.0127	2.4933	0.0178	7,030		125.13		
		TOTAL										991.32
Day 3	2	Face & Head Anterior	5	0.7034	0.0177	0.9848	0.0248		650		656.24	
		Neck Anterior	5	0.7618	0.0522	0.0655	0.0731		160		182.34	
		Head & Neck Posterior	5	1.1121	0.0269	1.5569	0.0377		300		478.38	
		Trunk, Anterior	5	0.7618	0.0522	1.0665	0.0731	3,700		270.47		
		Trunk, Posterior	5	1.1121	0.0269	1.5569	0.0377	3,330		125.54		
		Arms and Forearms	5	1.0116	0.0356	1.4162	0.0498	2,497.5		124.38		
		Thigh, Legs and Feet	5	1.1541	0.0427	1.6157	0.0598	7,030		420.39		
		TOTAL										2,257.74

TABLE 4 - (Continued)

Concentration of DEF Measured On Various Skin Areas of Flaggers
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A Hours of Exposure	Column B Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B Inside Gauze	Column C Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C Inside Gauze	Column D Area of Skin Surface (cm^2) Covered	Column D Bare	Column E Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E Bare Skin	Column F Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #1 Day 4	1	Face & Head Anterior		NS	NS	2.2481[a]	0.2419[a]		650		1,618.50	
		Neck Anterior		NS	NS	1.3668[a]	0.0322[a]		160		223.84	
		Head & Neck Posterior		NS	NS	4.9859[a]	0.2095[a]		300		1,558.62	
		Trunk, Anterior		NS	NS	1.3368[a]	0.0322[a]	3,700		119.14		
		Trunk, Posterior		NS	NS	4.9859[a]	0.2095[a]	3,330		697.64		
		Arms and Forearms	1	0.0089	0.0012	0.0623	0.0084	2,497.5		20.98		
		Thigh, Legs and Feet	1	1.3924	0.1911	9.7468	1.3377	7,030		9,404.03		
		TOTAL										13,642.75
Firm #2 Day 1	1	Face & Head Anterior	2	1.875	0.0130	6.5625	0.0455		650		4,295.2	
		Neck Anterior	7	2.8049	0.0738	2.8049	0.0738		160		460.59	
		Head & Neck Posterior	7	3.5714	0.2738	3.5714	0.2738		300		1,153.56	
		Trunk, Anterior	7	2.8049	0.0738	2.8049	0.0738	3,700		273.06		
		Trunk, Posterior	7	3.5714	0.2738	3.5714	0.2738	3,330		911.75		
		Arms and Forearms	7	3.2278	0.1646	3.2278	0.1646	2,497.5		411.09		
		Thigh, Legs and Feet	7	3.1646	0.3430	3.1646	0.3430	7,030		2,411.29		
		TOTAL										9,916.54

TABLE 4 - (Continued)

Concentration of DEF Measured On Various Skin Areas of Flaggers
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A Hours of Exposure	Column B Amount of DEF-6 On Cloth Pads (ug/cm^2) Outside Cloth	Column B Inside Gauze	Column C Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2) Outside Cloth	Column C Inside Gauze	Column D Area of Skin Surface (cm^2) Covered	Column D Bare	Column E Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms) Covered Skin	Column E Bare Skin	Column F Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
Firm #2 Day 1	2	Face & Head Anterior	2	2.0313	0.0286	7.1096	0.1001		650		4,686.31	
		Neck Anterior	7	3.9024	0.1366	3.9024	0.1366		160		646.24	
		Head & Neck Posterior	7	1.3024	0.0919	1.3024	0.0919		300		418.29	
		Trunk, Anterior	7	3.9024	0.1366	3.9024	0.1366	3,700		505.42		
		Trunk, Posterior	7	1.3024	0.0919	1.3024	0.0919	3,330		306.03		
		Arms and Forearms	7	2.2785	0.1487	2.2785	0.1487	2,497.5		371.38		
		Thigh, Legs and Feet	7	2.2152	0.3354	2.2152	0.3354	7,030		2,357.86		
		TOTAL										9,291.53
Day 2	1	Face & Head Anterior	1	4.375	0.1594	30.625	1.1158		650		20,631.52	
		Neck Anterior	7	2.6829	0.1463	2.6829	0.1463		160		452.67	
		Head & Neck Posterior	7	6.1905	0.4333	6.1905	0.4333		300		1,987.14	
		Trunk, Anterior	7	2.6829	0.1463	2.6829	0.1463	3,700		541.31		
		Trunk, Posterior	7	6.1905	0.4333	6.1905	0.4333	3,330		1,442.89		
		Arms and Forearms	7	8.9873	0.6272	8.9873	0.6272	2,497.5		1,566.43		
		Thigh, Legs and Feet	7	2.7848	0.3519	2.7848	0.3519	7,030		2,473.86		
		TOTAL										29,095.82

TABLE 4 - (Continued)

Concentration of DEF Measured On Various Skin Areas of Flaggers
During Aerial Defoliation of Cotton Fields by Two Applicator Firms in the
San Joaquin Valley of California in 1979

Firm No. And No of Days Studied	Worker Number	Skin Area Studied	Column A: Hours of Exposure	Column B: Amount of DEF-6 On Cloth Pads (ug/cm^2)		Column C: Estimated DEF Exposure Adjusted To 7-Hour Day (ug/cm^2)		Column D: Area of Skin Surface (cm^2)		Column E: Estimated Dermal DEF Exposure For 7-Hour Work Day (micrograms)		Column F: Total Dermal DEF Exposure Expected For Average 7-Hour Work Period (Excluding Hands) (micrograms)
				Outside Cloth	Inside Gauze	Outside Cloth	Inside Gauze	Covered	Bare	Covered Skin	Bare Skin	
Firm #2 Day 2	2	Face & Head Anterior	1	0.2594	0.0406	1.8158	0.2842		650		1,365	
		Neck Anterior	7	1.1793	0.1268	1.1793	0.1268		160		208.98	
		Head & Neck Posterior	7	4.7619	0.1134	4.7619	0.1134		300		1,462.59	
		Trunk, Anterior	7	1.1793	0.1268	1.1793	0.1268	3,700		469.16		
		Trunk, Posterior	7	4.7619	0.1134	4.7619	0.1134	3,330		377.62		
		Arms and Forearms	7	2.3418	0.1051	2.3418	0.1051	2,497.5		262.49		
		Thigh, Legs and Feet	7	2.0253	0.1253	2.0253	0.1253	7,030		880.86		
		TOTAL										5,026.7

[a] Estimated Value - Calculated by taking average of other flaggers with same firm for same skin area.

APPENDIX 1

Information on Fields Studied During Aerial
Defoliation of Cotton Fields Using DEF and Folex in the San Joaquin Valley
of California in 1979

	Firm 1, Day 1	Firm 1, Day 2	Firm 1, Day 3	Firm 1, Day 4	Firm 2, Day 1	Firm 2, Day 2
Pesticide Used	DEF-6	DEF-6	DEF-6	DEF-6	Folex	Folex
Application Rate/Acre	.22 G.P.A.	.25 G.P.A.	.25 G.P.A.	.22 G.P.A.	.25 G.P.A.	.25 G.P.A.
Carrier Used	Water	Water	Water	Water	Water	Water
Description of Aircraft	Turbo Prop	Turbo Prop	Turbo Prop	Turbo Prop	Thrush	Thrush
Volume of Spray Per Acre	10 Gallon	10 Gallon	10 Gallon	10 Gallon	10 Gallon	10 Gallon
Average Load Capacity	450 Gallon	450 Gallon	450 Gallon	400 Gallon	400 Gallon	400 Gallon
Description of Nozzles (Whirl Jets)	1/8 B10	1/8 B10	1/8 B10	1/8 B10	1/8 B10	1/8 B10
Droplet Size of Spray (Microns)	425	425	425	425	425	425
Flying Speed	130 MPH	130 MPH	130 MPH	130 MPH	115 MPH	115 MPH
Aircraft Height Above Crop	7 Feet	7 Feet	7 Feet	7 Feet	7 Feet	7 Feet
Hours Suitable for Spraying/Day	24 Hours	24 Hours	24 Hours	24 Hours	24 Hours	24 Hours
Actual Hours Spent Spraying	6-12	6-12	6-12	6-12	8-12	8-12
Average No. Acres Treated/Hour	175	175	175	175	150	150
Average No. Acres Treated/Day	1,000	1,000	1,000	1,000	1,000	1,000
Capacity of Batch Tank and Transfer System	100 Gallon	100 Gallon	100 Gallon	250 Gallon	1,000 Gallon	1,000 Gallon
Refill Time	1-1/2 Minutes	1-1/2 Minutes	1-1/2 Minutes	1-1/2 Minutes	2 Minutes	2 Minutes
Water Tank	2,200 Gallon	2,200 Gallon	2,200 GAllon	7,000 Gallon	2,200 Gallon	2,200 Gallon
Number of Mixer/Loaders	1	2	2	1	2	2
Number of Flaggers	3	2	2	1	2	2
Number of Pilots	2	2	2	1	2	2

Crop Information

Variety Tested	San Joaquin Acala	S. J. Acala	S. J. Acala	S. J. Acala	S. J. Acala	S. J. Acala
Stage of Growth	Mature	Mature	Mature	Mature	Mature	Mature
Climatic Conditions	Calm, Warm	Calm, Warm	Calm, Warm	Calm, Warm	Calm, Warm	Calm, Warm
Average Size Cotton Crop Field Acreage Treated	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres	1,000 Acres
Distance to Human Habitat	.5 Mile	.5 Mile	.5 Mile	Over .5 Mile	Over .3 Mile	Over .3 Mile
Did the Spray Drift Significantly	No	No	No	No	No	No

APPENDIX 2

List of other chemicals mixed with DEF and Folex for the various cotton defoliation applications studied.

Firm and Study Day Number	Trade Name	Registration Number
Firm 1	DEF 6	EPA 03125-00282 AA
Day 1	No Foam B	Ca. Reg. No. 50953-50001 AA
	Target	Ca. Reg. No. 36208-50013 AA
Day 2	DEF 6	EPA 03125-00282 AA
	No Foam B	Ca. Reg. No. 50953-50001 AA
	Target	Ca. Reg. No. 36208-50013 AA
Day 3	DEF 6	EPA 03125-00282 AA
	No Foam B	Ca. Reg. No. 50953-50001 AA
	Target	Ca. Reg. No. 36208-50013 AA
	Paraquat CL	EPA 00239-02186 AA
Day 4	DEF 6	EPA 03125-00282 AA
	Paraquat CL	EPA 00239-02186 AA
	ACCELERATE	EPA 04581-00284 AA
	NALCO-TROL	Ca. Reg. No. 01706-50001 AA
	Ortho spreader	Ca. Reg. No. 00239-50566 AA
	Sodium Chlorate	EPA 10951-50016 AA
Firm 2	Folex	EPA 02224-00017
Day 1 and Day 2	Paraquat CL	EPA 00239-02186 AA
	Bolls-Eye	EPA 06308-00091 AA
	Difolamax	Ca. Reg. No. 50962-50002
	NALCO-TROL	Ca. Reg. No. 01706-50001 AA

APPENDIX 3

Explanation of calculations used for the various columns of tables 2, 3, and 4.

Below are the methods of calculations used for tables 2-4:

Column C = $\frac{7 \times (\text{Column B})}{\text{Column A}}$

Column D : From Berkow (1931) and DuBois and DuBois (1916)

Column E = (Column C) x (Column D)

Column F: Sum of values from Column E.

Explanation for calculations used for various columns of Table 5.

Column B: Amount of DEF found by analysis in sample

Column C: $\frac{7 \times (\text{Column B})}{\text{Column A}}$

APPENDIX 4

Sample Extraction and Analysis for DEF

1. EXTRACTION

Air Samples

1. Resin Tubes - The tube is opened and divided into the front and back sections. Resin from each section is transferred to a small (5 ml) vial, and 2 ml of acetone is added. Samples are then extracted for one hour by rotation. The extracts are then adjusted to the desired volume and analyzed by gas chromatography.

2. Ethylene Glycol Impingers - The glycol trapping solution is transferred to a one liter separatory funnel with 600 mils of aqueous 2% sodium sulfate added. The sample is extracted with three 15 mil hexane washes. The hexane extracts are then combined and adjusted to 50 mls. Analysis is by gas chromatography.

Handwashes

Ethyl alcohol handwashes are filtered through a 0.2 micrometer filter and analyzed directly by gas chromatography.

Cloth and Gauze Patches

Each patch is extracted for one hour by rotating in a closed bottle with 50 mls of ethyl acetate. The volume is adjusted as necessary, and the sample is analyzed by gas chromatography.

2. ANALYSIS

Gas Chromatographs - Perkin-Elmer Model Sigma 2 with phosphorus specific detection (heated bead type).

Oven Temperature	220°C
Injector Temperature	225°C
Detector Temperature	350°C
Carrier Gas Flow Rate	N2 at 30 ml/min

Columns 6' x 2 mm glass, 4% OV101 on 100/120 mesh G.C.Q.
6' x 2 mm glass, 10% SP2100 on 100/120 mesh supelcoport

3. RECOVERY DATA

	Amount Added	Amount Recovered	% Recovery
Resin Tubes	100 ng/2 ml = 0.05 ng/ml	0.04 ng/ml	80.0%
	50 ng/2 ml = 0.025 ng/ml	0.018 ng/ml	72.0%
	Blank sample tube - None detected		
Ethylene Glycol	1 ng/50 ml = 0.02 ng/ml	0.018 ng/ml	90.0%
	1 ng/50 ml = 0.02 ng/ml	0.019 ng/ml	95.0%
	2 ng/50 ml = 0.04 ng/ml	0.039 ng/ml	97.5%
	Blank ethylene glycol - None detected		
Cloth & Gauze Patches (Combined)	0.25 mg/50 ml = 5 ng/ml	5.2 ng/ml	104.0%
	1.30 mg/50 ml = 26 ng/ml	26.3 ng/ml	101.0%
	2.56 mg/50 ml = 52 ng/ml	53.7 ng/ml	103.0%

Minimum Detectable Quantity

Tubes: 20 ng/total sample
Glycol: 100 ng/total sample
Patches: 100 ng/total sample

Note - PPB values are dependent on sampling time and pump flow rates. All air samples are corrected to 100% recovery.